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A comprehensive study of high frequency temporal chaotic behavior of riverine water quality dynamics

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Abstract: The dynamics of river water quality are complex, nonlinear, and influenced by various parameters. Therefore, studying nonlinear characteristics like chaos and fractals can have a significant impact on water quality prediction and soluble transport. However, most current research on the chaotic phenomenon of river water quality time series focuses only on the prediction model itself, with limited scientific investigation into pattern recognition, data mining, and systematic analysis of large-scale datasets. This study seeks to fill this gap by examining the chaos of river water quality, and discussing the potential relationships between chaos characteristics and water quality parameters. According to the richness of data and environmental diversity, we selected water quality time series from 12 automatic monitoring stations in Texas, USA for a systematic analysis of their chaotic characteristics (data source: USGS). The parameters measured included dissolved oxygen (DO), chemical oxygen demand (COD), pH, turbidity, and discharge. To represent univariate water quality data in multidimensional space and estimate the correlation dimension, we used the phase space reconstruction method and calculated the appropriate delay time (τ) for phase space reconstruction using the unbiased/multivariate autocorrelation coefficient method. We applied the Grassberger-Procaccia algorithm to calculate the embedding dimension (m) and correlation exponent (D).

The study results demonstrated that water quality in different locations exhibited varying degrees of chaotic behavior. Specifically, DO, pH, and turbidity exhibited low-to-mid-dimensional chaotic behavior, whereas the chaotic characteristics of flow and COD were negligible (<10%) in the study area. Notably, the likelihood of turbidity exhibiting chaos was 50%, with the common feature being that the majority of surrounding land use was residential, indicating high human activity levels. In terms of DO, the probability of chaotic behavior was highest in winter (approximately 83%), with autumn values surpassing those of summer. Autumn averages across all sites were also 10% higher than those in summer. Additionally, in areas with a good ecological environment, D in spring was significantly higher than it was in winter (37% on average). As for pH, spring and summer had a higher probability of exhibiting chaos than autumn and winter, with D in spring being higher than that in winter at the same site. Spring averages across all sites were also 25% higher than those in winter, reflecting the increased complexity of acid-base balance processes in water during the spring season.

This study will further analyze the differences in time series forecasting ability under different chaos characteristics and interpret the factors influencing chaos characteristics by considering the land use types in the upstream catchment area of the station. The results of this study will contribute to our understanding of the dynamic behavior of river water quality and help to improve the prediction accuracy of sub-basins.

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